# Hydrogen Fuel Cells for use as a renewable fuel source

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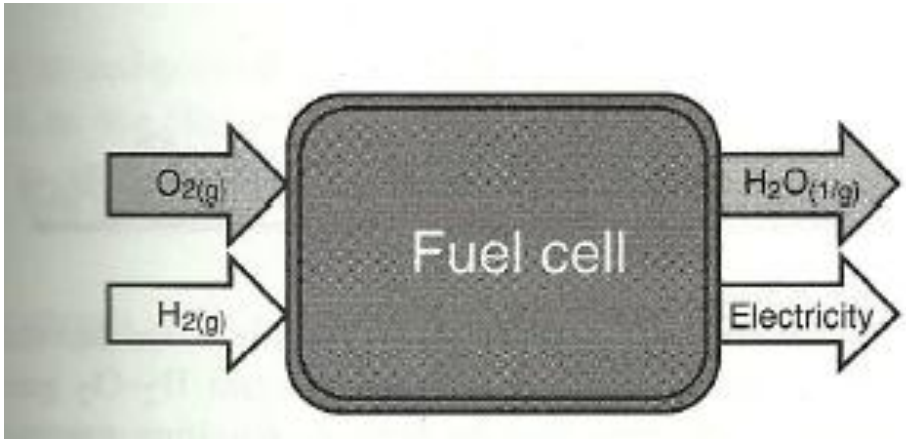
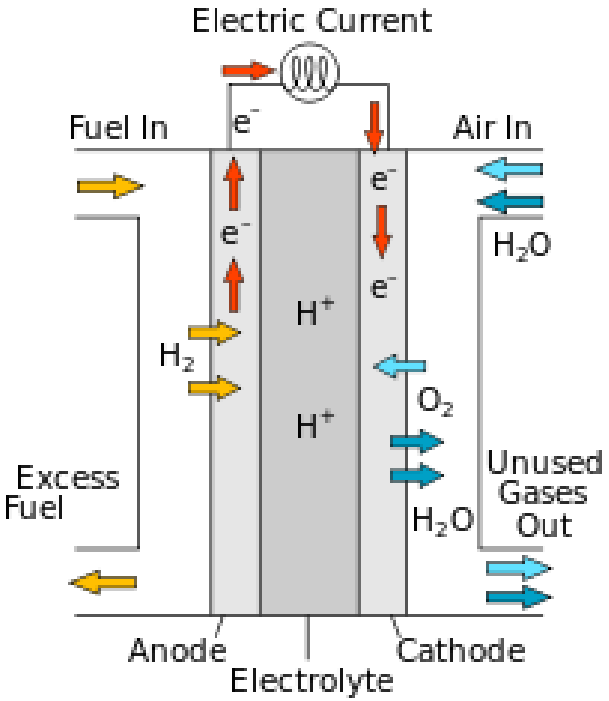
# General Overview of Fuel Cells




- Use chemical energy to produce electricity
- Can be thought of as a factory
  - Takes fuel and produces electricity
  - Will produce electricity as long fuel is supplied
- Different than an engine
  - No combustion involved
  - Small loss of heat

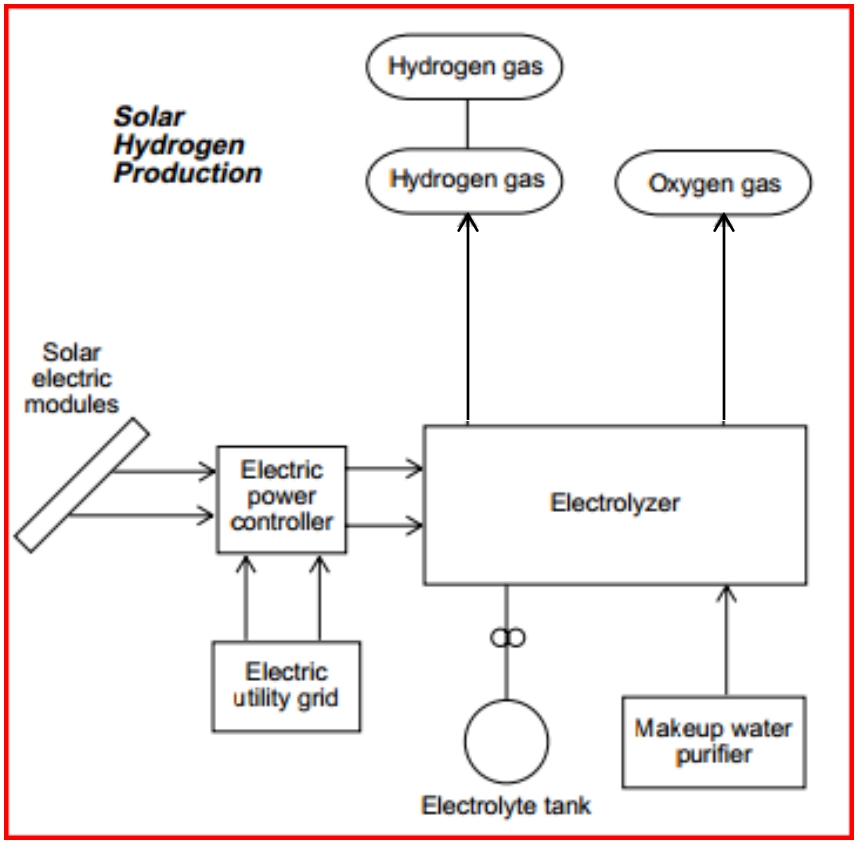
# Basic Overview of a Polymer Electrolyte Membrane Fuel Cell (PEMFC)




- Equations
  - Anode: $H_2 \rightarrow 2H^+ + 2e^-$
  - Cathode: $\frac{1}{2}O_2 + 2H^+ + 2e^- \rightarrow H_2O$
- Advantages
  - High power density
  - Relatively low-temperature operation
  - Good start/stop capabilities
- Disadvantages
  - Expensive
  - Active water management
  - Very poor CO and S tolerance

# Creation of Hydrogen by Electrolysis

- This is a basic home solar electrolysis diagram
- Creates Oxygen as a by-product which could be used for manned missions
- Hydrogen  created can be used directly in the hydrogen fuel cell



# Alternate Production of Hydrogen

## New Technology developed by MIT researchers

- Uses Nickel Borate ( $NiBO_3$ ) as a catalyst instead of expensive platinum
- Other compounds also viable but more research is needed

## Advantages

- Inexpensive Catalyst
- Uses solar energy as electrical source

## Disadvantages

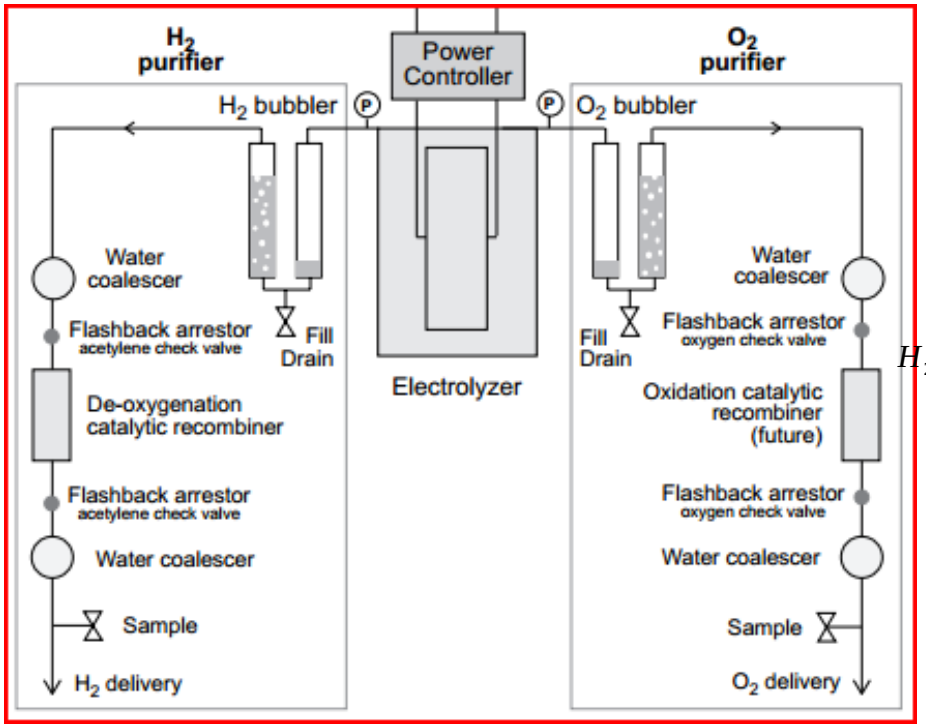
- Like all solar electrical sources it can only be viable to a certain point
- Untested technology in space
- Commercial electrolyzes have better performance at the moment

$$O_2 + 4H^+ + 4e^- \rightleftharpoons 2H_2O \qquad E_{anodic} = 1.23\,V - 0.059\,(pH)\,V \text{ vs NHE}$$

$$4H^+ + 4e^- \rightleftharpoons 2H_2 \qquad E_{cathodic} = 0\,V - 0.059\,(pH)\,V \text{ vs NHE}$$

$$2H_2O \longrightarrow 2H_2 + O_2 \qquad E_{rxn} = -1.23\,V$$

# Purification of Gases

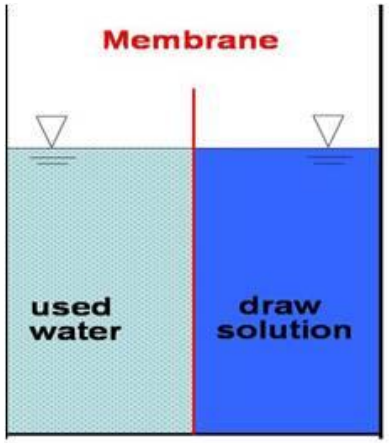


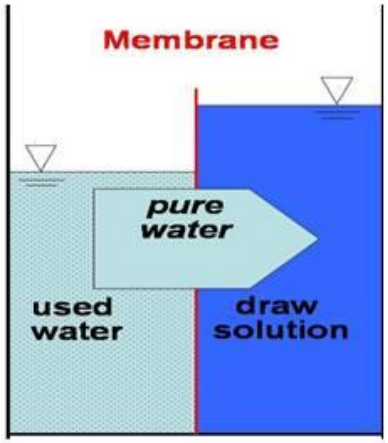

$H_2$

- The gases produced in the electrolysis must me purified in order to be used
- Both Hydrogen and Oxygen go through a similar process

# Recycling

- Urine can be converted to water using a process of forward osmosis
- This can be used for sustenance as well as fuel for the PEMFC fuel cell
- As stated before, a by-product electrolysis is oxygen

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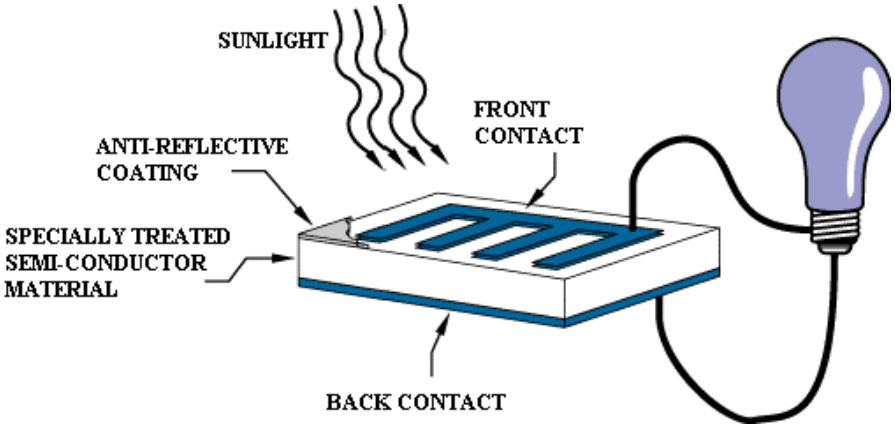
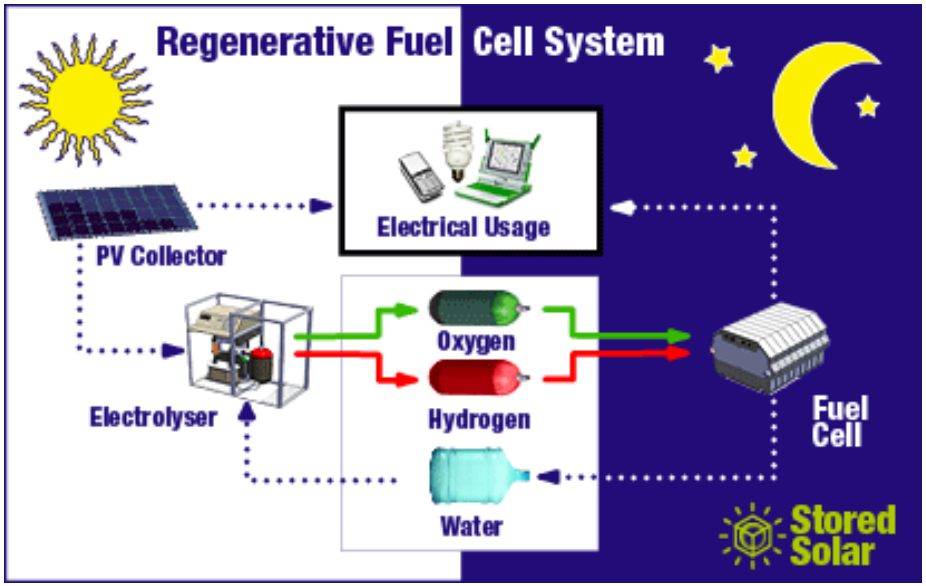
# Photovoltaic Cells

- Use the photoelectric effect to create energy
  - Creates DC Current
  - Can be wired in both parallel and series arrangements
- Semiconductors are the main photovoltaic cells used
- Uses in space
  - Sun's rays are unfiltered/weakened by Earth's electromagnetic field
  - Can focus on absorbing any spectrum of light emitted



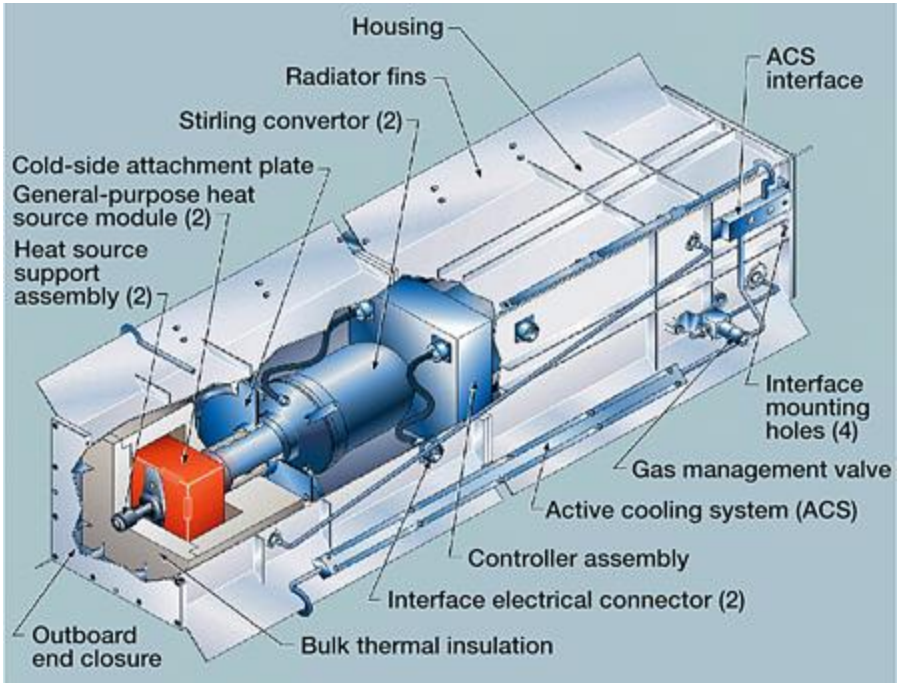
# Overall Space Exploration Concept




- The diagram to the left is an explanation of how a fuel cell can be self sustaining
- The fuel can be constantly made from solar output and then used in the fuel cell to produce electricity to power the ion thruster(s)
- PEMFC Hydrogen fuel cell is the ideal fuel cell to be used

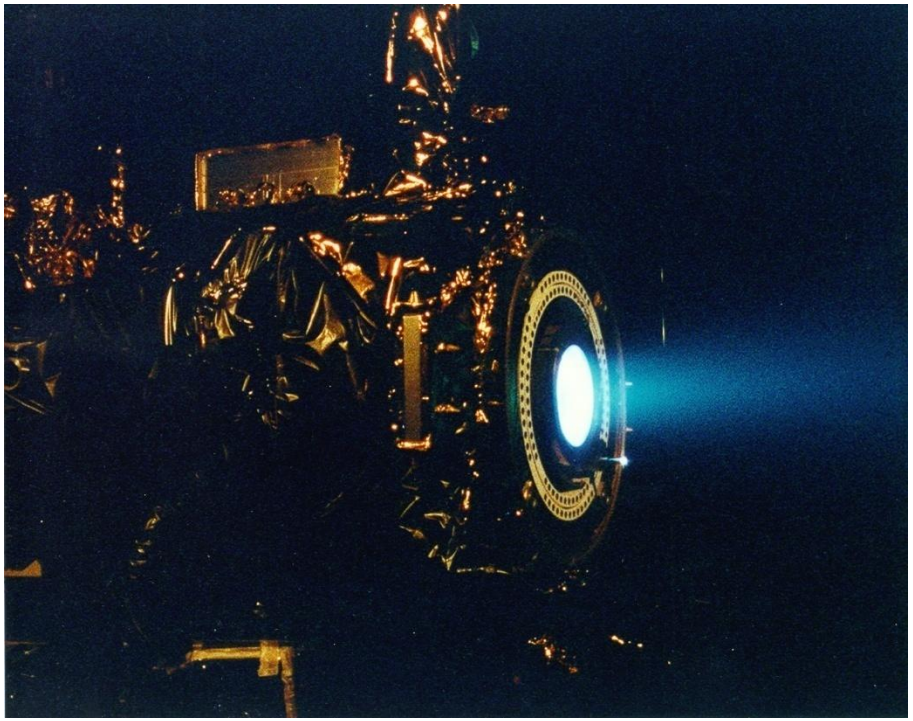
# Space Exploration

- Main idea is to combo the fuel cell with a proven technology for best results. Example: Radioisotope thermoelectric generator + PEMFC
- Advantages
  - Conserve fuel and energy of the fuel cell
  - Using both can increase speed of travel
- Disadvantages
  - Timing between technologies much be synced
  - Chance to contaminate fuel cell if built poorly



# Space Exploration (Cont.)

- PEMFC + small nuclear reactor
- Advantages
  - Travel beyond the range of the sun
  - Nuclear power has a high energy density
- Disadvantages
  - Expensive
  - Fuel storage space a problem
  - Nuclear power tried before and was shut down (NASA project Prometheus)



# Space Exploration (Cont.)

- Photovoltaic Cells + PEMFC
- Advantages
  - Can be at full power at begging of travel
  - Uses sun to maximum efficiency
  - For short missions great option
- Disadvantages
  - Uses for short duration missions
  - Loses effectiveness the father away from the sun

# Conclusion

- Hydrogen fuel cells are one of the emerging options in the area of sustainable space travel. The components required to build and sustain a PEMFC fuel cell are relatively cheap and will continue to become cheaper as the technology progresses. In combination with other technologies they have the potential to be useful additions to any deep space application. They provide recycling options which greatly increases their utility as well as their ability to be applied in manned space missions.

# References


1. Pyle, W., Healy, J., Cortez, R. (1994). Solar Hydrogen Production by Electrolysis. Retrieved from: http://www.dangerouslaboratories.org/h2homesystem.pdf
2. Bockris, J. O'M., Dandapani, B., Cocke, D., Ghorochchain, J. (18 September 1984). On the Splitting of Water. Int. J. Hydrogen Energy. Vol. 10. No. 30, pp. 179-201. Retrieved from: http://waterfuelcell.org/WFCprojects/SplitWater/bockris.pdf
3. O'Hayre, R., Cha, S., Colella, W., Prinz, F. (2006). Fuel Cells: Fundamentals. Hoboken, New Jersey: John Wiley & Sons, Inc.
4. Kanan, M., Nocera, D. (2008). In Situ Formation of an Oxygen-Evolving Catalyst in Neutral Water Containing Phosphate and Co2+. Science Mag, Vol. 321 no. 5892 pp.. 1072-1075. Retrieved from: http://www.sciencemag.org/content/321/5892/1072.abstract?ijkey=ba215da9c84cf9c6954cc95bd0eec5778db7f177&keytype2=tf_ipsecsha
5. Knier, G. (2002). How do Photovoltaics Work? Science.nasa.gov. Retrieved from: http://science.nasa.gov/science-news/science-at-nasa/2002/solarcells/